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(54) **VORTEX GENERATORS**

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B64C 23/00 (2006.01)
B64C 23/06 (2006.01)

(52) **U.S. Cl.**
CPC ***F15D 1/009*** (2013.01); ***B64C 23/005*** (2013.01); ***B64C 23/06*** (2013.01); *Y10T 137/2087* (2015.04)

(58) **Field of Classification Search**
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USPC 137/808, 809; 244/130, 199.1, 200.1, 244/201, 203, 204.1
See application file for complete search history.

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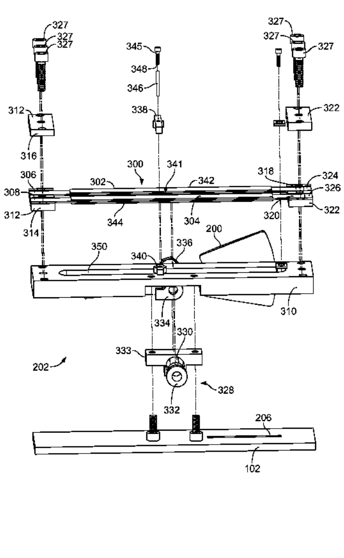
(57) **ABSTRACT**

Vortex generators are disclosed herein. An example apparatus includes a housing including a surface. The example apparatus also includes a bimorph actuator disposed in the housing. The bimorph actuator includes a first bimorph beam having a first portion fixed relative to the surface. A blade is rotatably coupled to the bimorph actuator, and the bimorph actuator is to rotate the blade to extend a portion of the blade through the surface to generate a vortex in a fluid flowing past the surface.

17 Claims, 11 Drawing Sheets



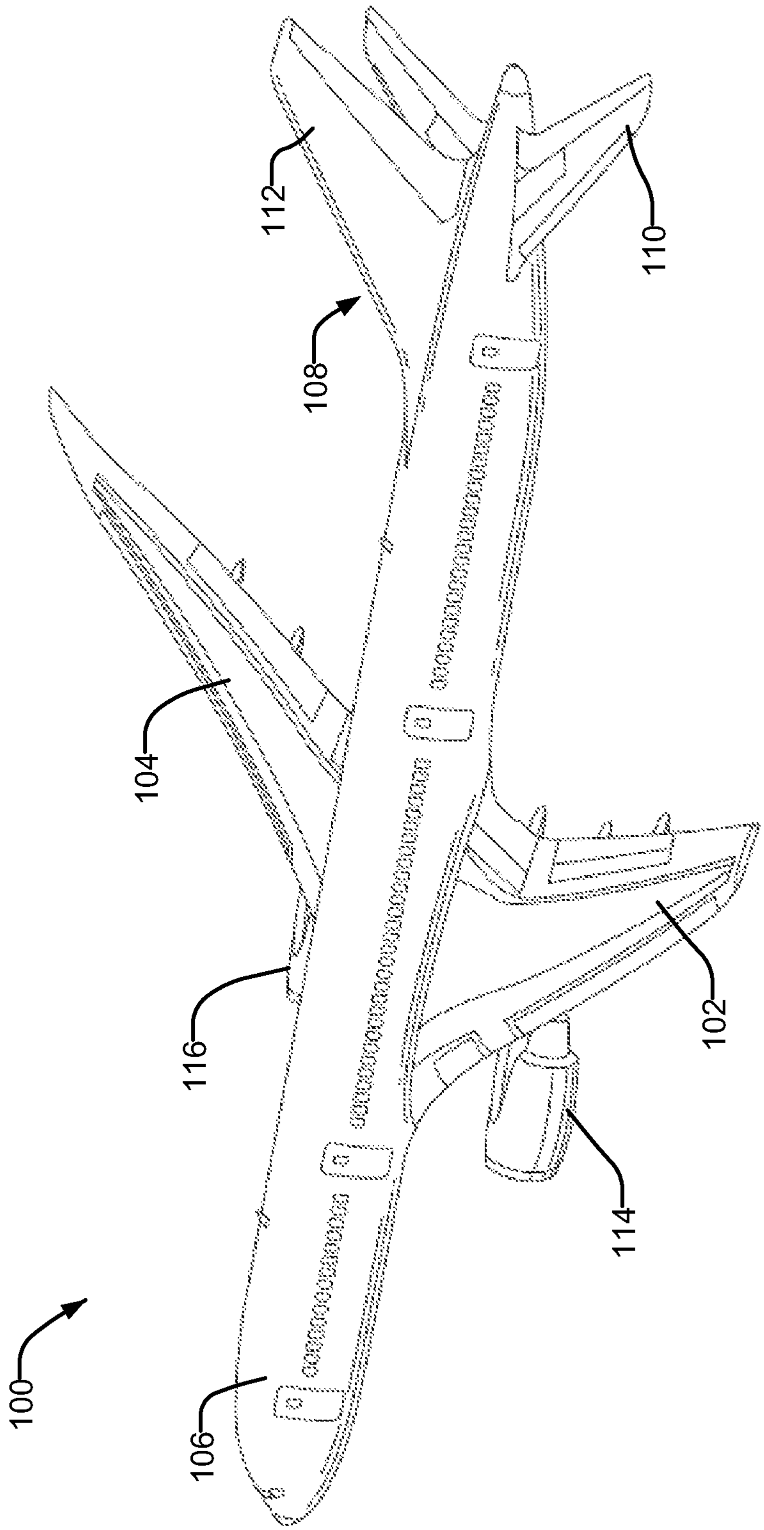


FIG. 1

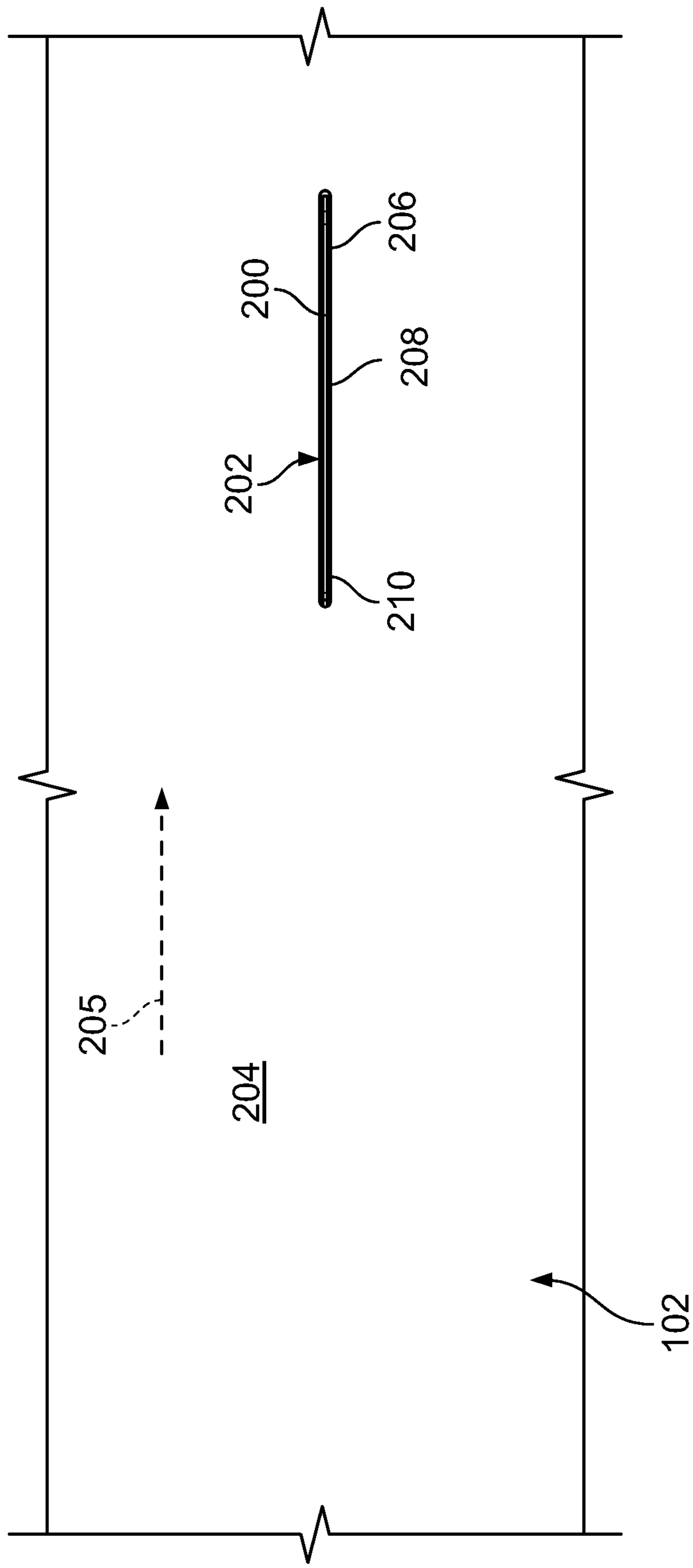
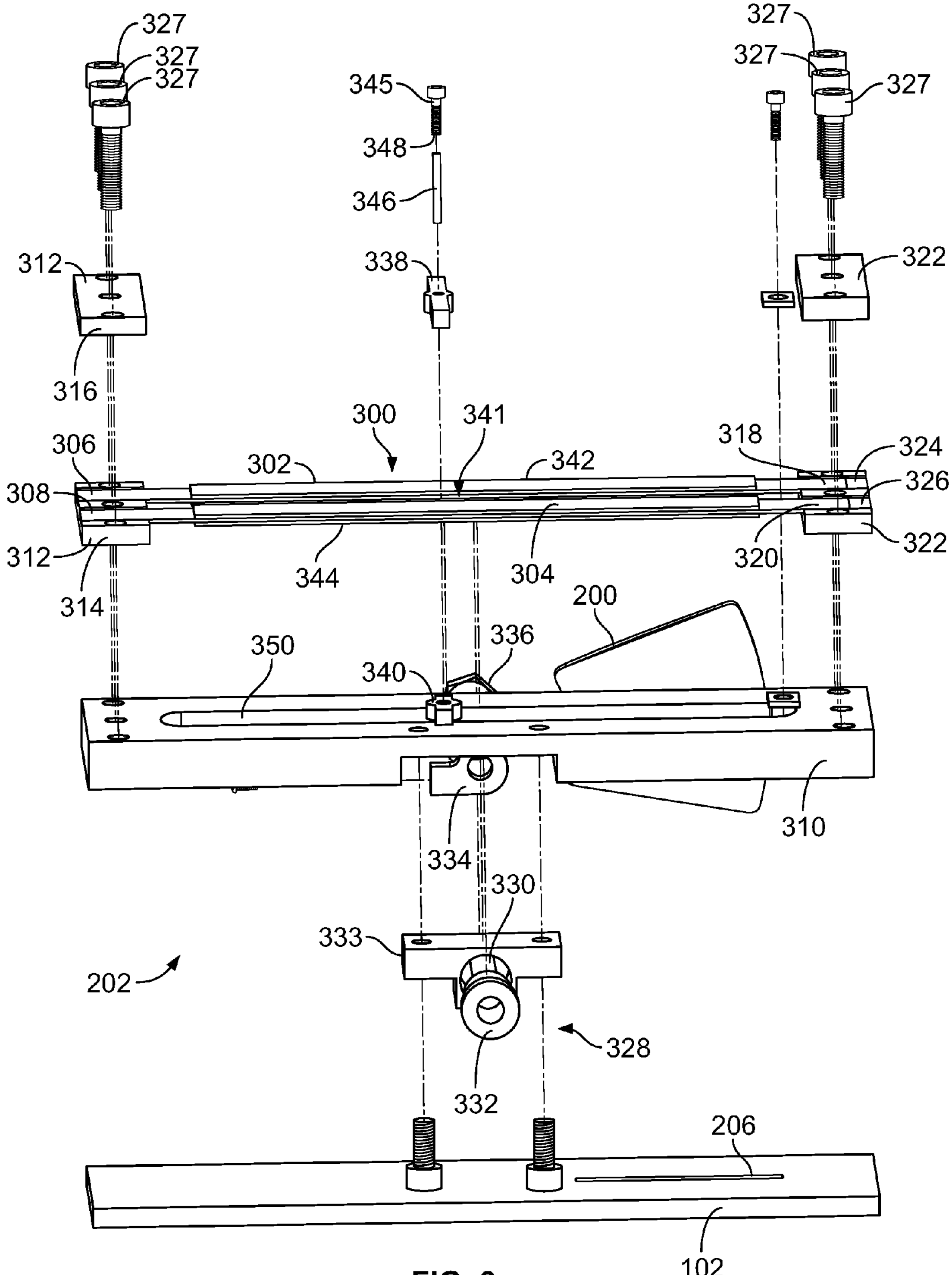


FIG. 2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308
326
312
344
304
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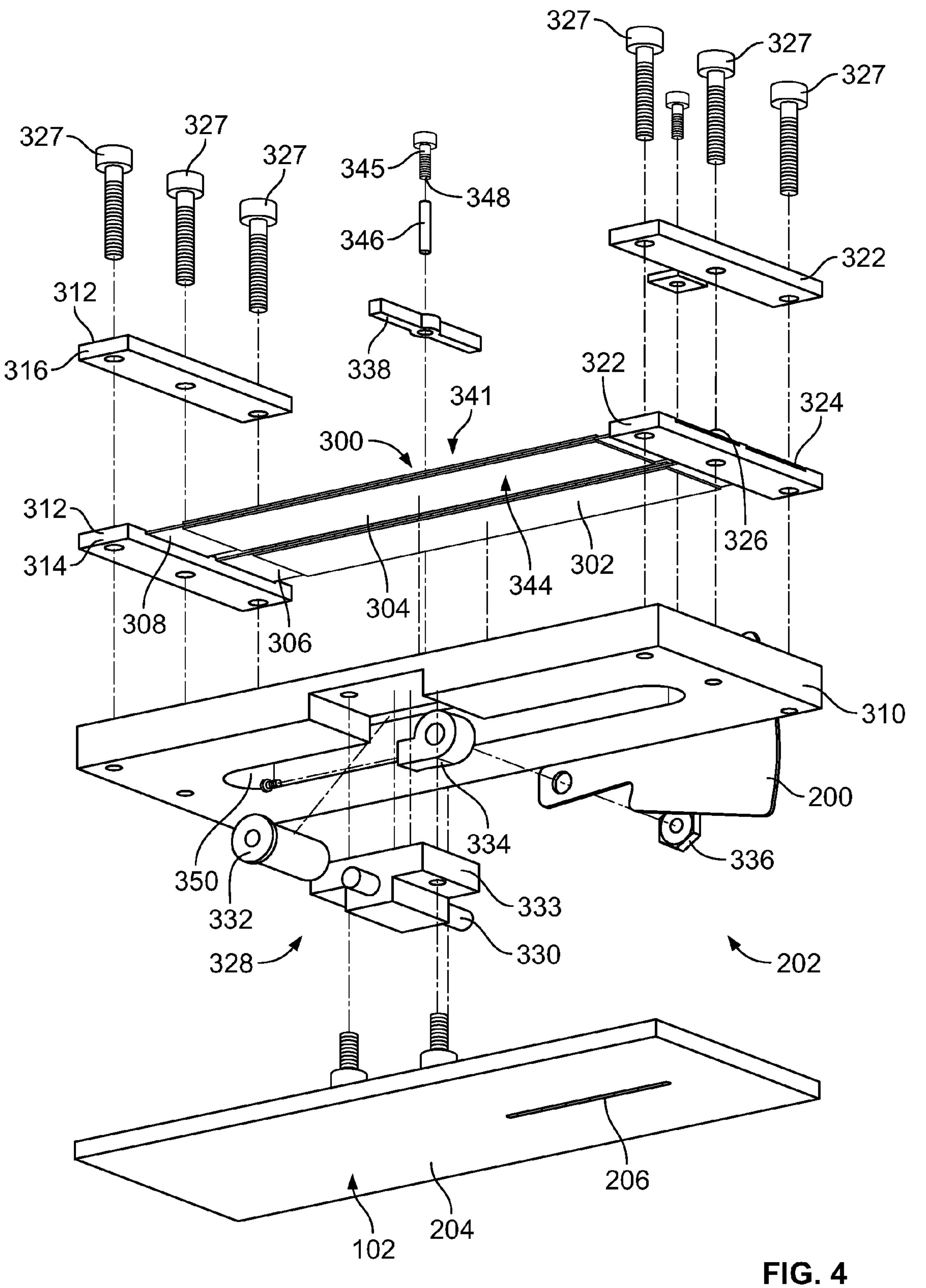
314
200
350
336
340
310
334
330
333
202
328
332
206
102

FIG. 3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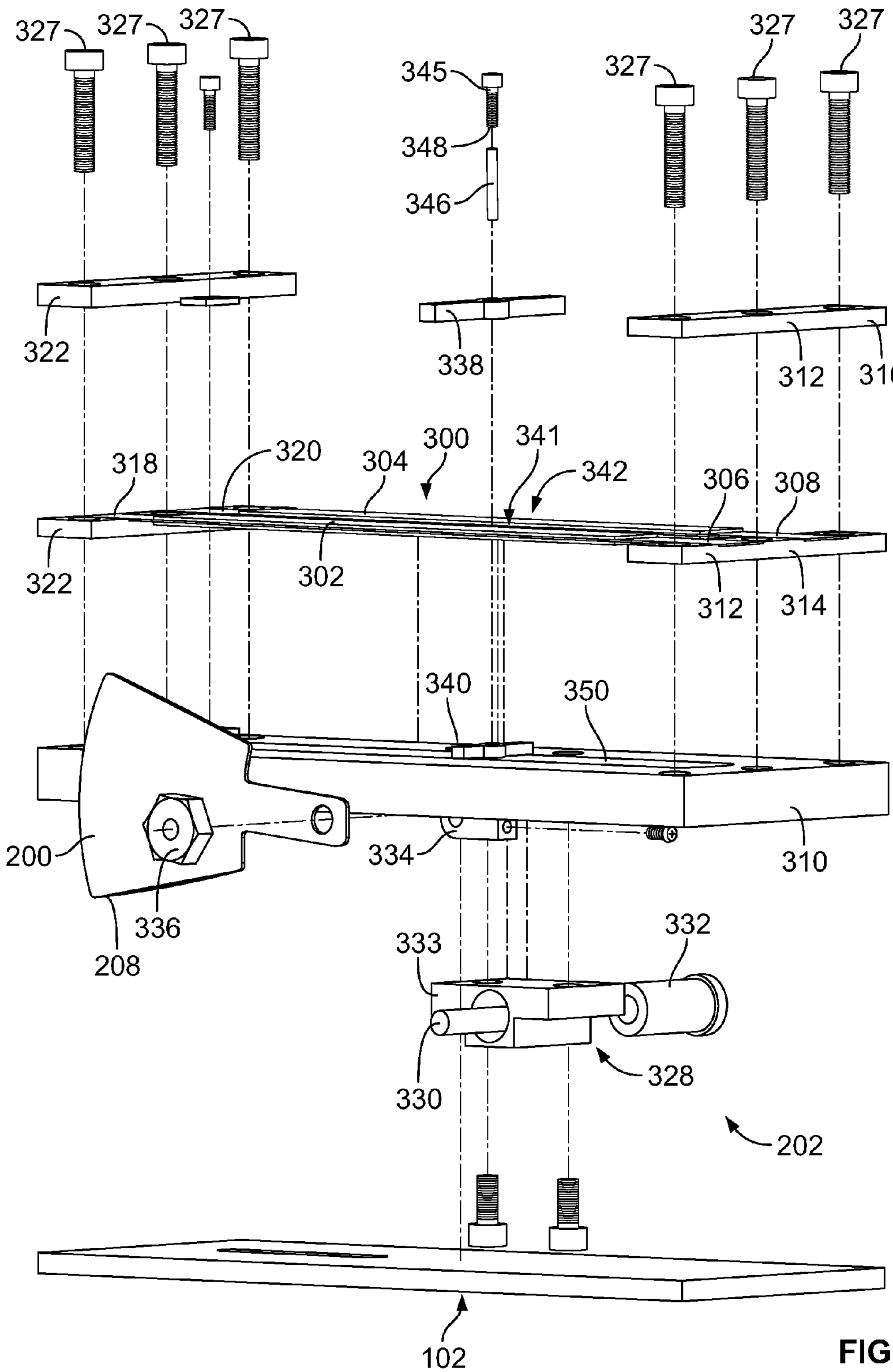
102

FIG. 4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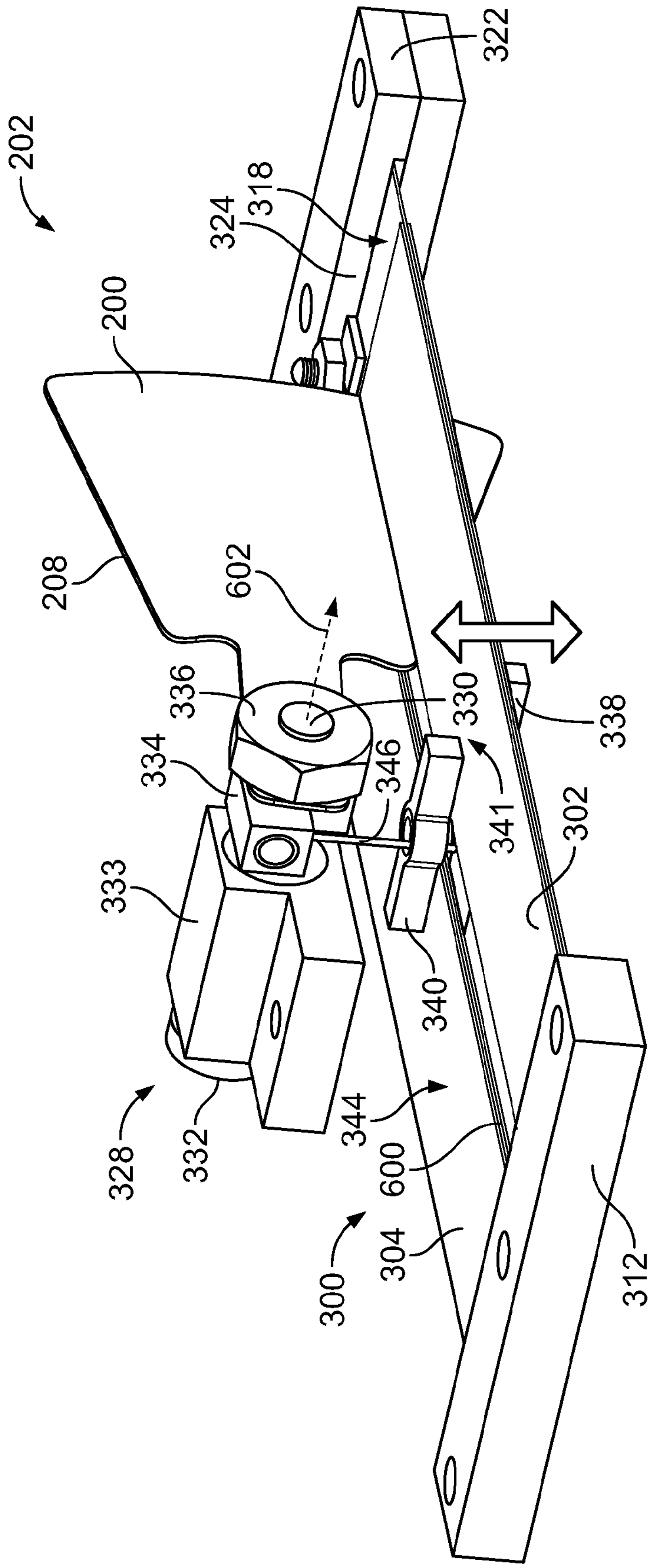
336
208
333
332
330
328
202
102

FIG. 5


202
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318
324
200
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602
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302
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600
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300
312

FIG. 6

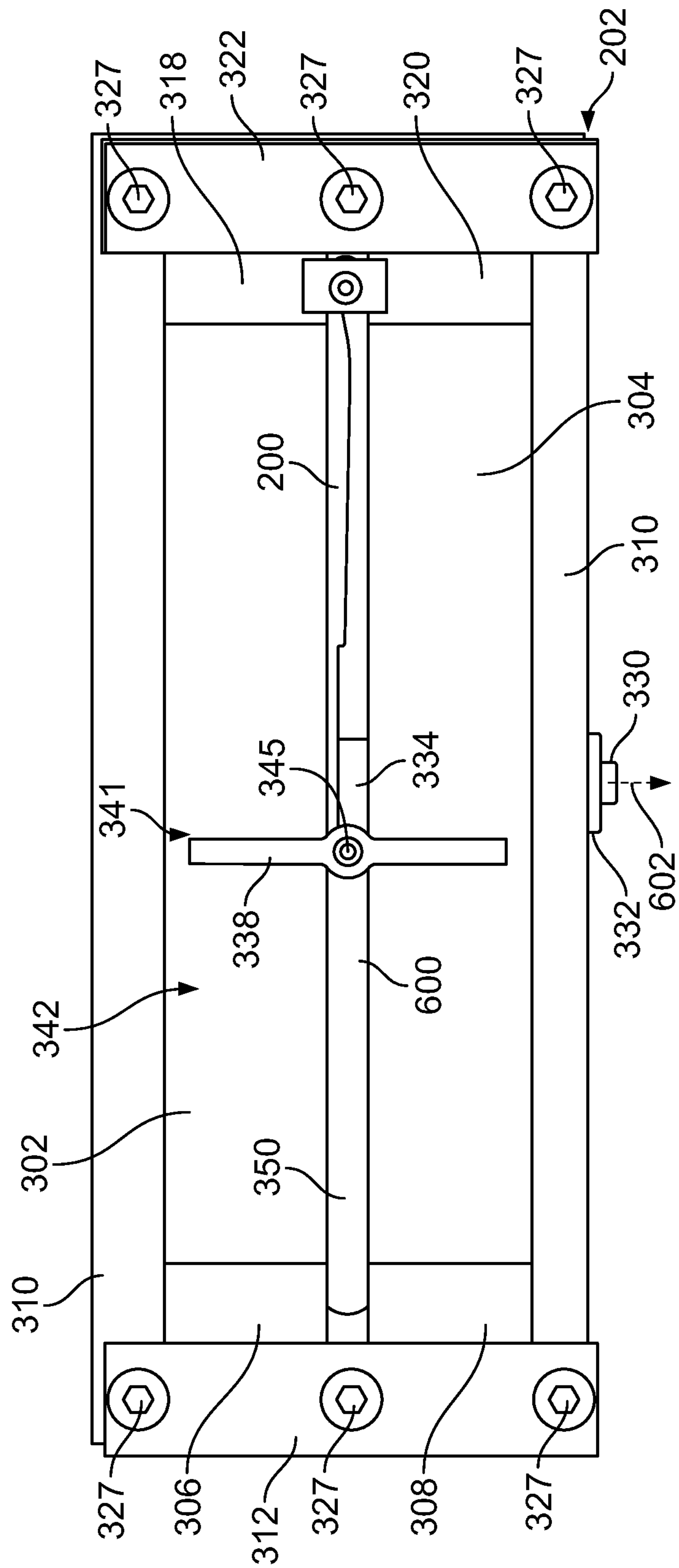
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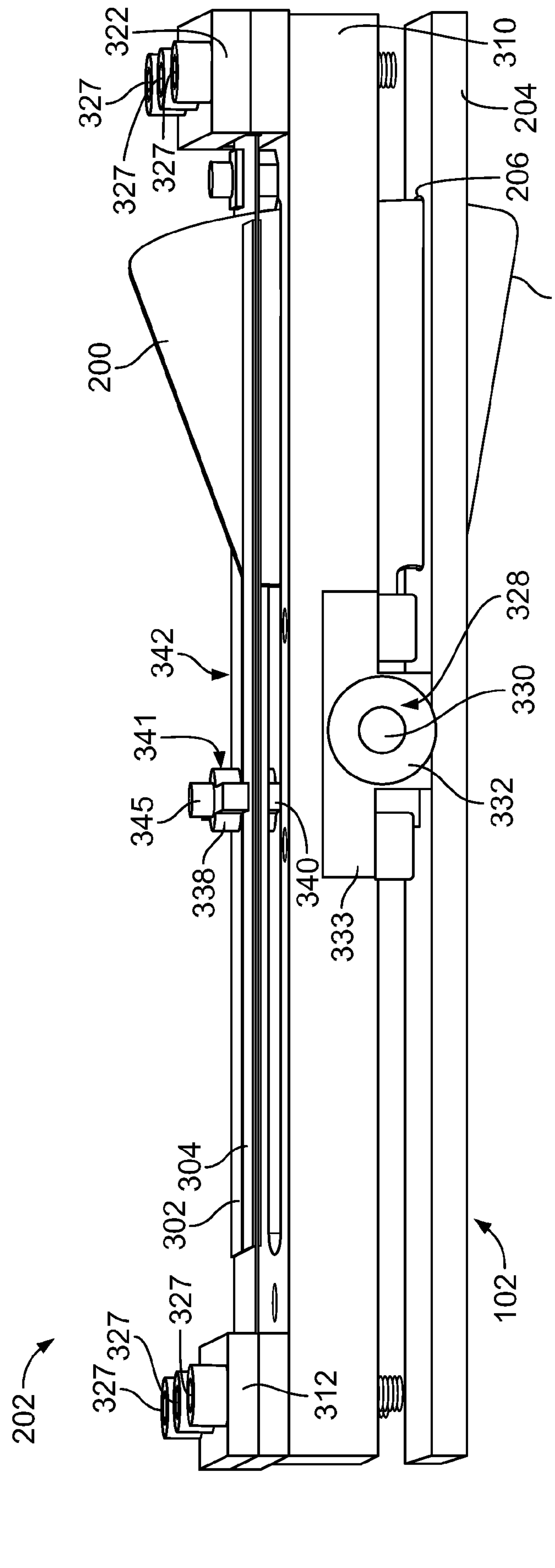
FIG. 7


322
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204
206
208
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342
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102
202
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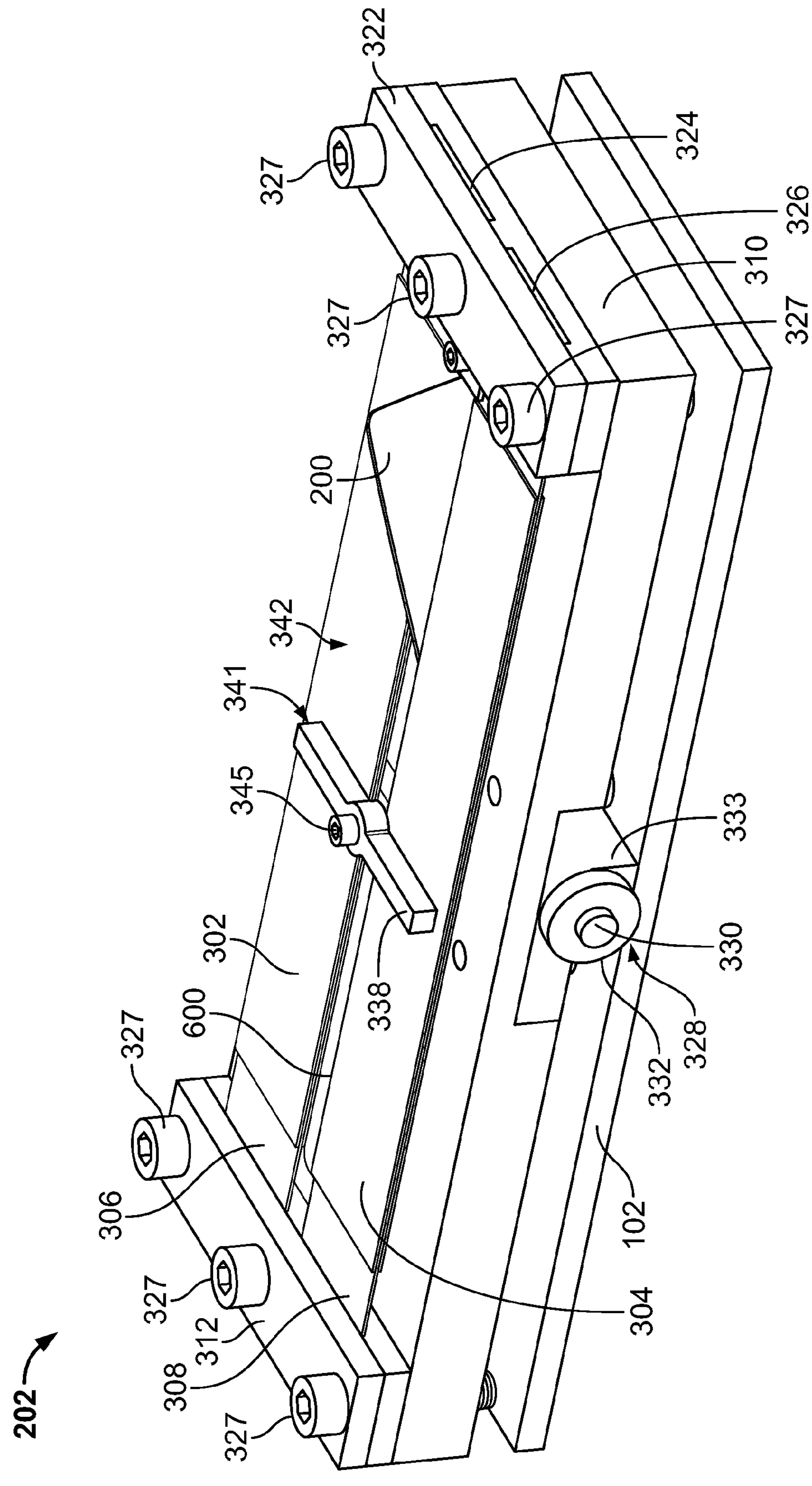
327
312

FIG. 8


322
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200
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306
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304
327
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308
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202

FIG. 9

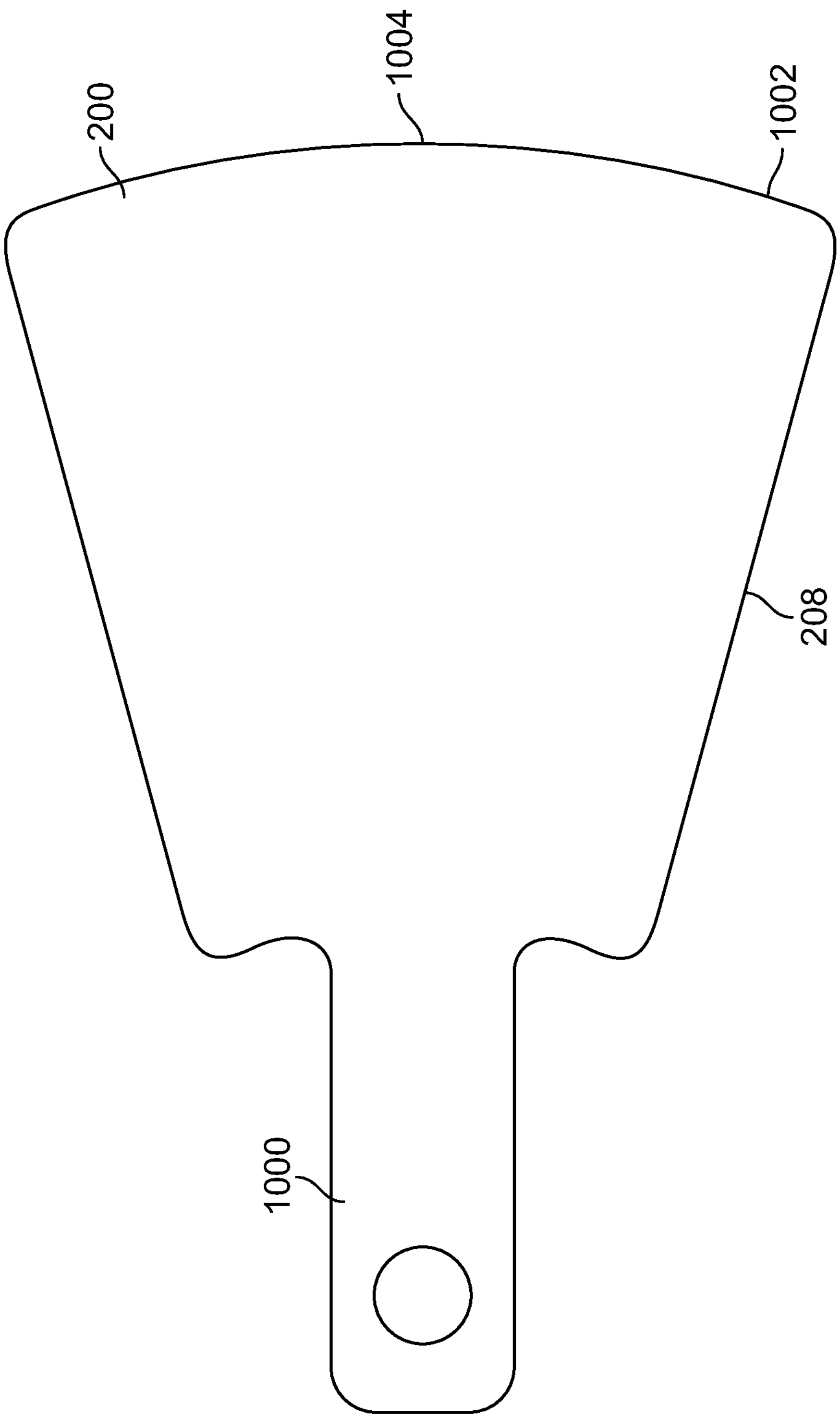

FIG. 10

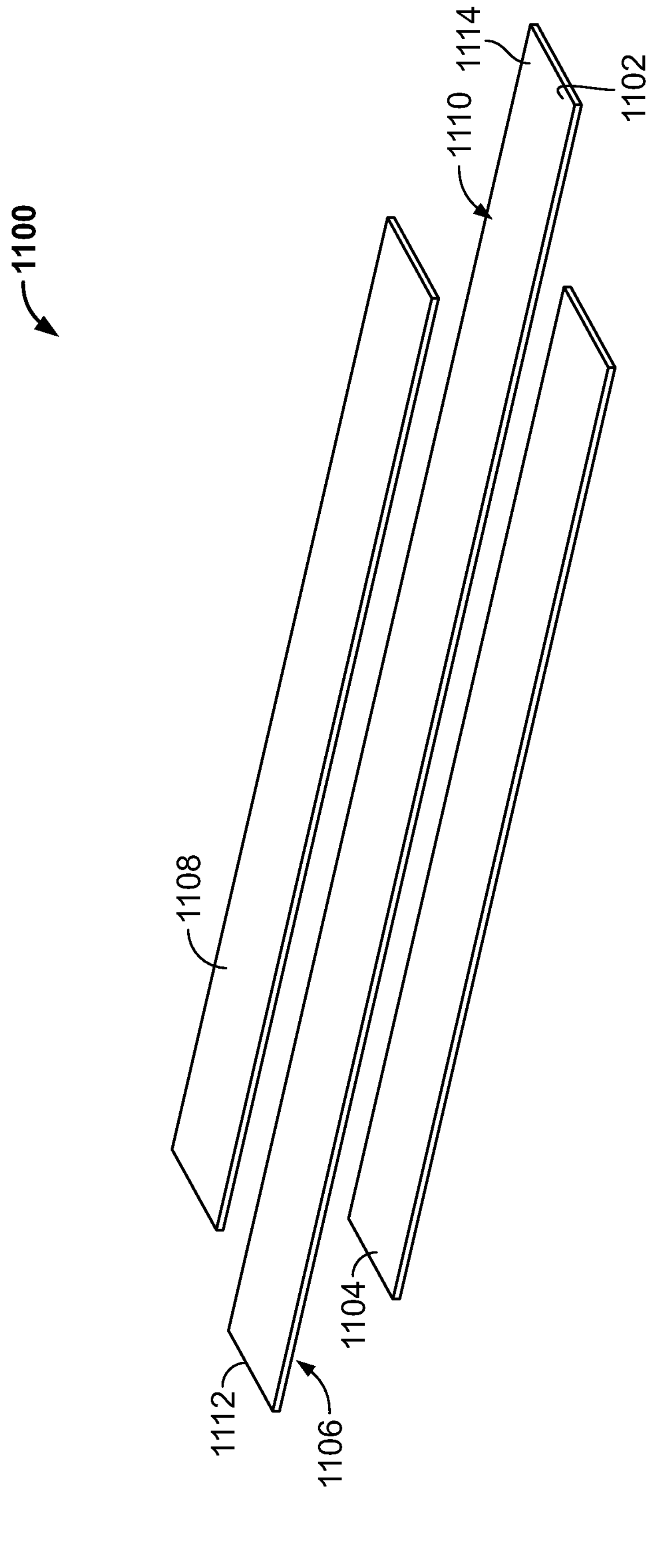

FIG. 11

VORTEX GENERATORS

FIELD OF THE DISCLOSURE

This disclosure relates generally to controlling fluid flow adjacent to a surface and, more particularly, to vortex generators.

BACKGROUND

Fluid flow adjacent to a surface may separate from the surface and produce drag. Traditionally, blades are fixed to the surface and extend into a boundary layer of the fluid flow to generate vortexes in the fluid flow. The vortexes draw fluid outside the boundary layer of the fluid flow toward the surface. As a result, separated fluid flow is reattached to the surface and/or separation of the fluid flow is reduced and/or delayed.

SUMMARY

An example apparatus includes a housing having a surface. The example apparatus also includes a bimorph actuator disposed in the housing. The bimorph actuator includes a first bimorph beam having a first portion fixed relative to the surface. A blade is rotatably coupled to the bimorph actuator, and the bimorph actuator is to rotate the blade to extend a portion of the blade through the surface to generate a vortex in a fluid flowing past the surface.

Another example apparatus includes a blade and a bimorph actuator operatively coupled to the blade. The bimorph actuator includes a fixed portion and a movable portion to enable deflection of the bimorph actuator to rotate the blade. The blade in a first position is to define a portion of a surface, and the blade in a second position is to generate a vortex in a fluid adjacent the surface.

Another example apparatus includes a bimorph actuator disposed in a housing defining a surface. The bimorph actuator has a first portion substantially stationary relative to the surface. The example apparatus also includes a blade operatively coupled to the bimorph actuator. Deflection of the bimorph actuator is to extend or retract the blade relative to the surface. An edge of the blade is to be in a first orientation relative to the surface when the blade is retracted, and the edge of the blade is to be in a second orientation relative to the surface when the blade is deployed.

The features, functions and advantages that have been discussed can be achieved independently in various examples or may be combined in yet other examples further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an example aircraft, which may be used to implement the example vortex generators disclosed herein.

FIG. **2** is a top view of a wing of the example aircraft of FIG. **1**, illustrating a blade of an example vortex generator disclosed herein.

FIG. **3** is an exploded view of the example vortex generator of FIG. **2**

FIG. **4** is another exploded view of the example vortex generator of FIGS. **2-3**.

FIG. **5** is another exploded view of the example vortex generator of FIGS. **2-4**.

FIG. **6** is a perspective, cutaway view of the example vortex generator of FIG. **2-5**.

FIG. **7** is a top view of the example vortex generator of FIG. **6**.

FIG. **8** is a side view of the example vortex generator of FIGS. **2-6**, illustrating the blade in a deployed position.

FIG. **9** is a perspective view of the example vortex generator of FIGS. **2-8**.

FIG. **10** is a side view of the example blade of the example vortex generator of FIGS. **2-9**.

FIG. **11** is an exploded view of an example bimorph beam constructed in accordance with the teachings of this disclosure.

The figures are not to scale. Instead, to clarify multiple layers and regions, the thickness of the layers may be enlarged in the drawings. Wherever possible, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts. As used in this patent, stating that any part (e.g., a layer, film, area, or plate) is in any way positioned on (e.g., positioned on, located on, disposed on, or formed on, etc.) another part, means that the referenced part is either in contact with the other part, or that the referenced part is above the other part with one or more intermediate part(s) located therebetween. Stating that any part is in contact with another part means that there is no intermediate part between the two parts.

DETAILED DESCRIPTION

An example vortex generator disclosed herein includes a bimorph actuator operatively coupled to a blade. The bimorph actuator may be disposed in a housing defining a surface of an airfoil. When the bimorph actuator is energized, the bimorph actuator moves the blade from a retracted position to a deployed position. When the blade is in the deployed position, the blade extends into and/or through a boundary layer of a fluid flowing past and/or adjacent to the surface to generate vortexes in the fluid. As a result, the example vortex generators prevent, reduce and/or delay separation of fluid flow from the surface and, thus, improve an aerodynamic performance of the surface by, for example, decreasing drag, mitigating stall phenomena, and/or improving an aerodynamic performance of the surface in other ways.

In some examples, the blade is in a first orientation when the blade is in the retracted position, and the blade is in a second orientation when the blade is in the deployed position. For example, an edge of the blade may be substantially flush with the surface when the blade is in the retracted position, and the edge may be angled away from the surface when the blade is in the deployed position. In some examples, the blade substantially fills a slot defined by the surface when the blade is in a retracted position, when the blade is in the deployed position and when the blade is positioned and/or moving between the retracted position and the deployed position.

In some examples, the bimorph actuator includes a first bimorph beam and a second bimorph beam. In some examples, the blade is rotatably coupled to the first bimorph beam and the second bimorph beam via a crank assembly. When the bimorph actuator is energized, the first bimorph beam and the second bimorph beam bend or deflect to drive the crank assembly to rotate the blade to and from the retracted position and/or the deployed position. In some examples, the first bimorph beam and the second bimorph beam each include a fixed portion and a movable portion. The fixed portions may be substantially stationary relative to the surface, and the moveable portions may be movable relative to the surface to enable deflection such as, for example, bowing of the first bimorph beam and the second bimorph beam when the bimorph actuator is energized.

FIG. **1** is a perspective view of an example aircraft **100** in which aspects of the present disclosure may be implemented. The example aircraft **100** of FIG. **1** includes a first wing **102**, a second wing **104** and a fuselage **106**. The example aircraft **100** also includes an empennage **108** having a horizontal stabilizer **110** and a vertical stabilizer **112**. In the illustrated example, the aircraft **100** includes a first engine **114** and a second engine **116**. As described in greater detail below in conjunction with FIGS. **2-10**, the example aircraft **100** employs example vortex generators disclosed herein, which generate vortexes adjacent one or more aerodynamic or airfoil surfaces of the aircraft **100**. However, the aircraft **100** of FIG. **1** is merely an example and, thus, other aircrafts may be used without departing from the scope of this disclosure. Further, while the following examples are described in conjunction with the example aircraft **100** of FIG. **1**, the example vortex generators disclosed herein may be used to generate vortexes in fluid flowing adjacent any surface. For example, the vortex generators may be used to generate vortexes adjacent a surface of a turbine blade, a ship, an automobile and/or a truck, a rotor, etc.

FIG. **2** is a top view of the example first wing **102** of the aircraft **100** of FIG. **1**, illustrating a blade **200** of an example vortex generator **202** and an aerodynamic surface **204** (e.g., skin) of the first wing **102**. The example blade **200** of FIG. **2** is substantially parallel to a direction of flow **205** of fluid (e.g., air) adjacent the surface **204**. While the example first wing **102** is illustrated as having one example vortex generator **202** and/or blade **200**, other examples include a plurality of vortex generators and/or blades. For example, the first wing **102** may include a row of blades, a symmetrical and/or an asymmetrical array of blades and/or blades arranged in any other pattern to generate vortexes in the fluid flowing adjacent any portion(s) of the surface **204**.

In the illustrated example, the blade **200** is in a retracted position. When the example blade **200** is in the retracted position, the blade **200** has a first orientation and substantially fills an aperture or first slot **206** defined by the surface **204**. In the illustrated example, a first edge **208** of the blade **200** in the retracted position is substantially flush with and/or level with the surface **204**. In some examples, a shape of the first edge **208** corresponds to a shape of the surface **204**. For example, in some examples, the surface **204** is substantially planar and the first edge **208** is substantially planar. In some examples, the surface **204** and the first edge **208** are curved and have substantially identical curvatures. As a result, when the example blade **200** is in the retracted position, the first edge **208** substantially forms a portion of the surface **204** and, thus, defines a portion of an airfoil of the first wing **102**. In some examples, when the example blade **200** is in the retracted position, an amount of drag produced by the vortex generator **202** is negligible. As described in greater detail below, the blade **200** may be oscillated between the retracted position and a deployed position to enable the vortex generator **202** to generate vortexes in the fluid flowing adjacent the surface.

In some examples, the blade **200** substantially fills the first slot **206** such that a gap **210** of five millimeters or less is present between the blade **200** and the surface **204** when the blade **200** is in the retracted position. As a result, the example blade **200** substantially obstructs the first slot **206** and prevents debris such as, for example, ice, dirt, etc. from entering the first wing **102** via the first slot **206**. The above-noted dimension of the first slot **206** is merely an example and, thus, other dimensions may be used without departing from the scope of this disclosure.

In some examples, a size of the first slot **206** is based on an experimentally determined slot. For example, in some examples, the blade **200** is pushed and/or punched through a curable structure such as, for example, an epoxy wall. The example blade **200** is then removed, and a size of an opening made in the structure is measured to determine the size of the first slot **206**. In some examples, instead of using the curable structure to determine measurements, the curable structure is employed on the example first wing **102**. For example, the first wing **102** may be constructed with an aperture larger than the first slot **206**. The example aperture is substantially filled with a curable substance such as, for example, an epoxy, and the blade **200** is punched through the substance to form the first slot **206**.

In the illustrated example, the first wing **102** houses the example vortex generator **202**. However, the first wing **102** is merely an example. In other examples, the example vortex generator **202** is disposed in other housings such as, for example, a turbine blade, a vehicle wall (e.g., a roof of a trailer of a truck), and/or any structure defining at least a portion of an aerodynamic surface and/or an airfoil.

FIGS. **3-5** are exploded views of the example vortex generator **202** of FIG. **2**. In the illustrated example, the vortex generator **202** includes a bimorph actuator **300** having a first bimorph beam **302** and a second bimorph beam **304**. In the illustrated example, when the bimorph actuator **300** is energized, the first bimorph beam **302** and the second bimorph beam **304** bend or deflect. In the illustrated example, the first bimorph beam **302** and the second bimorph beam **304** have first ends **306**, **308** fixedly coupled to a base **310** via a first support **312**. More specifically, in the illustrated example, the first ends **306**, **308** of the first bimorph beam **302** and the second bimorph beam **304** are clamped between a first portion **314** and a second portion **316** of the first support **312**, and the first portion **314** is coupled to the base **310**. In other examples, the first ends **306**, **308** are fixedly coupled to the base **310** in other ways. In some examples, the base **310** is fixedly coupled to the first wing **102** and, thus, the first ends **306**, **308** of the first and second bimorph beams **302**, **304** are fixed or substantially stationary relative to the first wing **102** and/or the surface **204**.

Second ends **318**, **320** of the example first bimorph beam **302** and the example second bimorph beam **304** are supported by and slidably coupled to the base **310** via a second support **322**. In the illustrated example, the second support **322** defines a first channel **324** and a second channel **326**. In the illustrated example, the second ends **318**, **320** of the first bimorph beam **302** and the second bimorph beam **304** are disposed in the first channel **324** and the second channel **326**, respectively. The example first channel **324** and the example second channel **326** enable translational movement of the second ends **318**, **320** relative to the second support **322**. In some examples, the first channel **324** and the second channel **326** guide the translational movement of the second ends **318**, **320** and facilitate bending of the first bimorph beam **302** and the second bimorph beam **304**. In some examples, the first channel **324** and the second channel **326** reduce and/or substantially prevent twisting of the first bimorph beam **302** and the second bimorph beam **304**, respectively. Thus, the example first bimorph beam **302** and the example second bimorph beam **304** may bow. In the illustrated example, the first support **312** and the second support **322** are coupled to the base **310** via fasteners **327**. The example fasteners **327** of FIGS. **3-5** are bolts. In other examples, other types of fasteners such as, for example, screws, adhesives, welds, etc. are employed.

When the example bimorph actuator **300** is energized via a first electrical signal, the example first bimorph beam **302** and the example second bimorph beam **304** bend or deflect away from the first wing **102** from an unactuated position to an actuated position. If the example bimorph actuator **300** is then de-energized (e.g., if transmission of the first electrical signal is ceased), the example first bimorph beam **302** and the example second bimorph beam **304** returns to the unactuated position. If a second electrical signal is supplied to the example bimorph actuator **300**, the first bimorph beam **302** and the example second bimorph beam **304** bend or deflect toward the first wing **102**. In other examples, the bimorph actuator **300** actuates in other ways.

In the illustrated example, the first support **312** is spaced apart from the second support **322**, and the first bimorph beam **302** and the second bimorph beam **304** bridge the first support **312** and the second support **322**. The example first bimorph beam **302** and the example second bimorph beam **304** are spaced apart from the base **310** via the first support **312** and the second support **322**. As a result, when the bimorph actuator **300** actuates, the first bimorph beam **302** and the second bimorph beam **304** bend or deflect without contacting the base **310**.

In the illustrated example, the blade **200** is rotatably coupled to the bimorph actuator **300** via a crank assembly **328**. In the illustrated example, the crank assembly **328** includes a shaft **330** supported via a bearing **332** disposed in a bearing housing **333**. The example bearing housing **333** is coupled to the base **310**. The example shaft **330** is coupled to a bell crank **334** and the blade **200**. The example blade **200** of FIGS. **3-5** is secured to the crank assembly **328** via a nut **336**. In some examples, a position sensor is operatively coupled to the crank assembly **328** to monitor a position of the blade **200**.

In the illustrated example, a first tie **338** and a second tie **340** are coupled to the bimorph actuator **300** between the first ends **306**, **308** and the second ends **318**, **320** of the first bimorph beam **302** and the second bimorph beam **304**. In some examples, the first tie **338** and the second tie **340** are coupled to a middle portion **341** of the bimorph actuator **300**. The example middle portion of the bimorph actuator **300** is substantially equidistant to the first ends **306**, **308** and the second ends **318**, **320**. In other examples, the first tie **338** and the second tie **340** are coupled to other portions of the bimorph actuator **300**. In the illustrated example, the first tie **338** is disposed on a first side **342** of the bimorph actuator **300**, and the second tie **340** is disposed on a second side **344** of the bimorph actuator **300**. In the illustrated example, the first tie **338** is coupled to the second tie **340** via a fastener **345** (e.g., a bolt) to clamp the bimorph actuator **300** between the first tie **338** and the second tie **340**. Thus, when the example first bimorph beam **302** and the example second bimorph beam **304** bend or deflect, the first tie **338** and the second tie **340** move with the first bimorph beam **302** and the second bimorph beam **304**.

The example bell crank **334** is coupled to the first tie **338** and/or the second tie **340** via an arm **346**. In some examples, the arm **346** is a wire or cable. In the illustrated example, the arm **346** couples the bell crank **334** to the first tie **338** and/or the second tie **340** by extending from an end **348** of the fastener **345** to the bell crank **334** via a second slot **350** defined by the base **310**. In other examples, the arm **346** is implemented in other ways.

FIGS. **6-7** illustrate the example vortex generator **202** of FIGS. **2-5**. FIG. **6** is a perspective view of the example vortex generator **202** shown inverted relative to the orientation of the vortex generator **202** in FIGS. **3-5**. FIG. **7** is a bottom view of the example vortex generator **202** of FIG. **6**. In the illustrated example, the first bimorph beam **302** and the second bimorph beam **304** are spaced apart to define a space or third slot **600** between the first bimorph beam **302** and the second bimorph beam **304**. In the illustrated example, the first tie **338** and the second tie **340** extend across and/or span the third slot **600**. In the illustrated example, a portion of the blade **200** is disposed in the third slot **600**.

In the illustrated example, when the bimorph actuator **300** is energized, the middle portion **341** of the bimorph actuator **300** bends or deflects away from the bell crank **334** and the first wing **102** (FIGS. **1-5**). In some examples, a maximum amount of deflection of the first bimorph beam **302** and/or the second bimorph beam **304** is two millimeters. In other examples, the bimorph actuator **300** bends or deflects other amounts. The first tie **338** and the second tie **340** move with the bimorph actuator **300** and drive the arm **346** to rotate the bell crank **334** about an axis of rotation **602** defined by the shaft **330**. As a result, the example blade **200** rotates about the axis of rotation **602** from the retracted position (FIG. **2**) to the deployed position (FIG. **7**). In the illustrated example, when the bimorph actuator **300** bends or deflects, the second ends **318**, **320** of the first bimorph beam **302** and the second bimorph beam **304** slide within the first channel **324** and the second channel **326**, respectively. The example blade **200** in the deployed position generates a vortex in the fluid flowing adjacent the surface **204**. In some examples, the bimorph actuator **300** is actuated to move between the retracted position and the deployed position at a predetermined frequency to generate an oscillatory stream of vortexes in a boundary layer of the fluid flowing adjacent the surface **204** of the first wing **102**.

FIGS. **8-9** illustrate the example vortex generator **202** of FIGS. **2-7** having the example blade **200** in the deployed position. FIG. **8** is a side, cutaway view of the example vortex generator **202**. FIG. **9** is a perspective view of the example vortex generator **202**. The example blade **200** in the deployed position substantially fills the first slot **206**. In the illustrated example, when the blade **200** is in the deployed position, the first edge **208** of the blade is in a second orientation. In the illustrated example, the blade **200** is angled approximately fifteen degrees away from a direction of flow of the fluid adjacent the surface **204**. In other examples, the blade **200** and/or the first edge **208** are oriented in other ways. The example blade **200** of FIGS. **8-9** extends into and/or through the boundary layer of the fluid flowing adjacent the surface **204** of the first wing **102** to generate vortexes in the fluid. When the example blade **200** generates vortexes, the vortexes draw fluid from outside the boundary layer of the fluid toward the surface **204**. As a result, separated flow is reattached and/or flow separation is reduced and/or delayed, improving an aerodynamic performance of the aircraft **100**. For example, drag on the aircraft **100** may be decreased, stall phenomena affecting the aircraft **100** may be mitigated, and/or the aerodynamic performance of the aircraft **100** may be improved in other ways.

FIG. **10** is a side view of the example blade **200** of FIGS. **2-9**. In the illustrated example, the blade **200** includes a flange **1000**. The example blade **200** couples to the crank assembly **328** via the flange **1000**. In the illustrated example, the first edge **208** is disposed at an angle (e.g., fifteen degrees) relative to the flange **1000**. The example first edge **208** of FIG. **10** is substantially planar. In other examples, the first edge **208** is not planar. For example, the first edge **208** may be curved. In the illustrated example, the blade includes a second edge **1002** defining an end **1004** of the blade **200**. In the illustrated example, the second edge **1002** is curved. In other examples, the second edge **1002** is other shapes (e.g., planar). The above-noted shapes of the blade **200** are merely examples. In other examples, the blade **200** is other shapes. For example, the blade may be a shape described in U.S. Pat. No. 8,047,233, which was filed on Nov. 14, 2007, entitled "Apparatus and Method for Generating Vortexes in Fluid Flow Adjacent to a Surface," which is hereby incorporated herein by reference in its entirety and/or any other shape.

FIG. **11** illustrates an example bimorph beam **1100**, which may be used to implement the example first bimorph beam **302** and/or the example second bimorph beam **304** of the example bimorph actuator **300** of FIGS. **3-9**. In the illustrated example, the bimorph beam **1100** includes a flexible substrate sheet **1102** having a first length. In some examples, the substrate sheet **1102** is a uniaxial prepreg carbon sheet. A first piezoelectric wafer **1104** is coupled to a first side **1106** of the example substrate sheet **1102**. A second piezoelectric wafer **1108** is coupled to a second side **1110** of the example substrate sheet **1102**. In some examples, the first piezoelectric wafer **1104** and/or the second piezoelectric wafer **1108** have thicknesses between 0.13 millimeters and 0.5 millimeters. In other examples, the first piezoelectric wafer **1104** and/or the second piezoelectric wafer **1108** have other thicknesses. In the illustrated example, the first piezoelectric wafer **1104** and the second piezoelectric wafer **1108** have a second length shorter than the first length and are substantially centrally located on the substrate sheet **1102**. As a result, a first end **1112** and a second end **1114** of the substrate sheet **1102** are not covered by the first piezoelectric wafer **1104** and/or the second piezoelectric wafer **1108**. In some examples, the bimorph beam **1100** is supported via the first end **1112** and the second end **1114** of the substrate sheet **1102**. As a result, when the example bimorph beam **1100** bends, the first end **1112** and/or the second end **1114** may rotate and, thus, function as pivot points and/or hinges.

When an electrical signal is supplied to the example bimorph beam **1100**, the bimorph beam **1100** bends or deflects. In some examples, a first voltage having a first polarity is applied to the first piezoelectric wafer **1104** and a second voltage having a second polarity is applied to the second piezoelectric wafer **1108**. As a result, the first piezoelectric wafer **1104** elongates and the second piezoelectric wafer **1108** shortens. When the first piezoelectric wafer **1104** elongates and the second piezoelectric wafer **1108** shortens, the example bimorph beam **1100** bends or deflects. In some examples, a maximum amount of deflection of the bimorph beam **1100** is two millimeters. In other examples, the bimorph beam **1100** deflects other amounts. In some examples, polarities of the first voltage and the second voltage are cyclically alternated or switched to cause the bimorph beam **1100** to oscillate between a first position and a second position. In some examples, the bimorph beam **1100** is constructed and/or operated in accordance with the teachings of U.S. Pat. No. 7,681,290, filed Oct. 20, 2006, entitled "Piezoelectric Bimorph Beam Manufacturing Method," which is hereby incorporated herein by reference in its entirety. In other examples, the bimorph beam **1100** is constructed and/or operated in other ways.

From the foregoing, it will be appreciated that the above disclosed vortex generators generate vortexes in fluid flowing adjacent to a surface. The example vortex generators disclosed herein include blades that are deployed through slots in the surface to extend into and/or through a boundary layer of the fluid. When the generation of vortexes in the fluid is not desired, the blades of the example vortex generators disclosed herein may be retracted to be substantially flush with the surface such that the example vortex generators produce substantially no additional and/or collateral drag on the surface. The example blades substantially fill the slots when the blades are in a retracted position, when the blades are in a deployed position and when the blades are positioned and/or moving between the retracted position and the deployed position. As a result, the example vortex generators disclosed herein are less susceptible to an incursion of debris such as ice, dirt, etc. than traditional dynamic vortex generators.

Although certain example methods, apparatus and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all methods, apparatus and articles of manufacture fairly falling within the scope of the claims of this patent.

What is claimed is:

1. An apparatus comprising:

a housing including a surface;

a bimorph actuator disposed in the housing, the bimorph actuator including a first bimorph beam and a second bimorph beam spaced apart from the first bimorph beam, the first bimorph beam having a first portion fixed relative to the surface; and

a blade rotatably coupled to the bimorph actuator, the bimorph actuator to rotate the blade to extend a portion of the blade through the surface to generate a vortex in a fluid flowing past the surface, wherein the blade is disposed in a space between the first bimorph beam and the second bimorph beam when the blade is in a retracted position.

2. The apparatus of claim **1** further comprising a tie coupled to the first bimorph beam and the second bimorph beam, deflection of the first bimorph beam and the second bimorph beam to move the tie.

3. The apparatus of claim **2** further comprising an arm coupled to the tie and the blade, wherein movement of the tie is to drive the arm to rotate the blade.

4. The apparatus of claim **3** further comprising a crank operatively coupled to the arm and the blade, wherein movement of the arm is to rotate the crank and the blade.

5. The apparatus of claim **1**, wherein an edge of the blade is substantially flush with the surface when the blade is in the retracted position.

6. An apparatus comprising:

a housing including a surface;

a bimorph actuator disposed in the housing, the bimorph actuator including a first bimorph beam having a first portion fixed relative to the surface, wherein the first portion is fixedly coupled to a base, and a second portion of the first bimorph beam is slidably coupled to the base; and

a blade rotatably coupled to the bimorph actuator, the bimorph actuator to rotate the blade to extend a portion of the blade through the surface to generate a vortex in a fluid flowing past the surface.

7. The apparatus of claim **6**, wherein the blade substantially fills a slot extending through the surface.

8. An apparatus comprising:

a blade; and

a bimorph actuator operatively coupled to the blade, the bimorph actuator including a fixed portion and a movable portion to enable deflection of the bimorph actuator to rotate the blade, the blade in a first position to define a portion of a surface, the blade in a second position to generate a vortex in a fluid adjacent the surface, wherein the movable portion of the bimorph actuator is disposed in a slot defined by a base, the slot to guide translational movement of the moveable portion of the bimorph actuator.

9. The apparatus of claim **8**, wherein the fixed portion of the bimorph actuator is fixedly coupled to the base.

10. The apparatus of claim **8**, wherein the surface defines an aperture, the blade to be disposed in the aperture when the blade is in the first position and the second position.

11. The apparatus of claim **10**, wherein a shape of an edge of the blade corresponds to a shape of the surface.

12. The apparatus of claim **8**, wherein the blade is to extend through the surface to the second position when the bimorph actuator deflects away from the surface.

13. An apparatus, comprising:

a bimorph actuator disposed in a housing defining a surface, the bimorph actuator having a first portion substantially stationary relative to the surface and a second portion slidably coupled to the surface; and

a blade operatively coupled to the bimorph actuator, deflection of the bimorph actuator to extend or retract the blade relative to the surface, an edge of the blade to be in a first orientation relative to the surface when the blade is retracted, the edge of the blade to be in a second orientation relative to the surface when the blade is deployed.

14. The apparatus of claim **13**, wherein the edge in the first orientation is substantially flush with the surface.

15. The apparatus of claim **13**, wherein the edge in the second orientation is to be angled away from the surface.

16. The apparatus of claim **13**, wherein a maximum amount of the deflection of the bimorph actuator is to occur at a middle portion of the bimorph actuator.

17. The apparatus of claim **13**, wherein the blade is to rotate relative to the surface to extend or retract the blade.

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